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PRELIMINARY DESIGN OF LARGE SCALE DIRECT SHEAR APPARATUS

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1. INTRODUCTION

The mechanical behaviour of a rock mass involves the combined effects of the intact rock material, as well as the joint systems. A good understanding of both systems is required before the appropriate constitutive models can be developed to represent an overall rock mass behaviour.

In view of the difficulties associated with the quantitative estimation of rock joint properties on the basis of existing techniques, a contract was issued to Terra Tek Inc. of Salt Lake City, Utah, to provide a mechanical and hydraulic model for characterizing rock joint systems. Additionally, the contractor was to provide a methodology for field tests, and for collecting the necessary rock joint parameters, required as input data for the joint model.

The rock joint contract was fully discharged in 1983. A model for evaluating the coupled mechanical-hydraulic properties of joints, as well as a methodology for collecting field data were provided (Barton and Bakhtar, 1983). The data collection methodology has since been applied to Lac du Bonnet area core samples. The objective of the study was to characterize the research area rock joints on the basis of the Barton-Bandis joint model (Barton and Bakhtar, 1983).

If this method is to be an effective tool for modellers, values determined using core joint couples must be capable of being scaled to reflect the in situ condition. With this in mind, CANMET has undertaken to conduct large scale shear tests on jointed samples which have been previously characterized using the Barton-Bandis model. Briefly, the effects of scale on such things as peak shear strength, displacement to peak strength, joint dilation and joint hydraulic conductivity both under ambient and elevated temperature conditions will be studied. Properties determined in this study will be compared to values arrived at using scaling factors suggested by the model and core data.

The purpose of this report is to outline the design of the large scale shear apparatus being fabricated by CANMET to conduct the test program.

2. DESIGN CONSIDERATIONS

As the name implies, the large scale shear apparatus has been designed to accommodate samples considerably larger than those which can currently be tested with commercially available equipment. Specimens to be studied as part of the scale effects program will have contact areas ranging anywhere from 40 cm^2 to 600 cm^2. Length to width ratios of approximately 3:2 are generally recommended for direct shear testing (1), which leads to maximum design sample dimensions of 30 cm by 20 cm.

It was felt that if joint dilation and the consequent increase in hydraulic conductivity were to be studied, normal stresses of the order of 0.001 to 0.1 MPa would be sufficient. This also corresponds to the range of normal stresses over which validity is claimed for the Barton-Bandis model. Values reported in the literature indicate that peak shear strengths at this level of normal loading can range between 0.5 and 5 times the applied normal stress (2). Therefore, for a 30 cm x 20 cm sample subjected to a normal stress of 0.1 MPa, a shearing force as high as 30 kN might be anticipated.

Simulation of near field conditions in a nuclear waste vault requires that the shear test equipment be able to perform at elevated temperatures up to 200°C. Methods are not only required to obtain different target temperatures but also to obtain them at different specified heating rates and maintain them over varying periods. A system of sensors will also be required in order to record the temperature profile across the test specimen.

Traditionally, shear displacement rates varying from 2.5 to 7.5 mm/min are used at CANMET. Overall shear displacement is usually set to 1/3 of the sample length (1). Design displacement rates, then, will vary between 1.0 and 10.0 mm/min with a maximum displacement of 10 cm. Displacement in both the normal and shear directions should be capable of being measured to within 0.02 mm.

The overall design considerations, therefore, can be summarized as:

maximum sample size:	30 cm by 20 cm
maximum normal load:	6.0 kN
maximum shear load:	30.0 kN
temperature range:	ambient to 200°C
heating rate:	0.1 to 5°C/min
displacement rate:	1.0 to 10.0 mm/min
overall displacement:	10 cm

3. EQUIPMENT DESIGN

Considerable thought was given as to which half of the shear box the shear force would be applied. While often times it is transferred via the top half of the shear box, measurement of normal displacement is generally not a consideration and its accurate measurement not required. In this instance, however, joint dilation and the accompanying changes in hydraulic conductivity are a primary concern and their accurate measurement of paramount importance. It was decided, then, that the upper box should be constrained from moving in the direction of shearing and simply allowed to move normal to the joint surface (i.e., dilation). This greatly facilitates the development of a normal displacement measurement system as well as a method of applying normal loads which will remain constant throughout a test.

3.1 UPPER SHEAR BOX

Both the upper and lower shear boxes were fashioned from a 12 x 20.7 ft/lbX26LG steel u-channel. As can be seen in Fig. 1, the upper shear box is fitted with a shaft at one end. Bearings have been installed on this shaft in such a way that they will mate with channels secured to the shear apparatus base plate (see Fig. 3). These bearings will allow the box to ride up and down relatively friction-free while the channels restrict horizontal movement.

Four mica strip heaters have been secured to the top of the box both mechanically and using heat transfer compound. These have been sized and situated to provide as uniform a temperature profile as possible over the 30 cm by 20 cm sample size. Allowance has been made for the installation of an array of thermocouples which will surround the cemented specimen and provide analog outputs of its temperature profile.

3.2 LOWER SHEAR BOX

As Fig. 2 illustrates, the lower shear box is also equipped with the same type of heating strips as are employed in the upper box. A strain gauged push block assembly is secured to the loading face by four bolts. This may be removed and replaced with a proving ring or load cell if increased resolution is required.

The lower box will slide on three 2.54 cm wide brass strips secured to the apparatus base plate. The strips were chosen to facilitate the machining of a perfectly flat surface over which the lower box can slide. It also affords the opportunity to test alternate materials to minimize the sliding friction without replacing the entire base plate.

3.3 LOADING MECHANISM

An hydraulic loading system requires considerable peripheral instrumentation if it is required to maintain a constant displacement rate. For this reason, a 50 kN machine screw actuator was chosen to supply the load. Power requirement calculations included that a 1/2 HP variable speed electric motor is capable or providing the required force at the design displacement rates. The actuator, itself, requires 40 turns of the worm gear to travel 1 cm while the electric motor is capable of varying its speed from 50 to 1600 rpm. The speed of the motor was reduced by supplying a 30:1 in line gear reducer. The combination of actuator, reducer and variable speed motor allows displacement rate control ranging from 0.4 to 13 mm/min.

3.4 PARAMETER MEASUREMENT

Normal dilation will be measured utilizing four LVDT's situated at the four corners of the upper shear box. This arrangement should enable the normal displacement as well as the joint alignment to be determined at any point during the test. Shear displacement will also be measured using LVDT's attached to the free end of the lower shear box.

The heating rate will be controlled by a device already developed at CANMET for previous studies and should be easily adapted for use in this program. Analog signals including those obtained from LVDT's, thermocouples and the appropriate load measuring device will be fed into a Fluke 2280A datalogger which will record the output at designated intervals throughout the test.

3.5 BASE PLATE AND MOUNTING BRACKETS

The base was fabricated from a 61 cm by 173 cm by 1 cm steel plate. The plate was stiffened by spot welding three 3X4.10 ft/lbX68LG steel u-channels to its underside as illustrated in Fig. 3.

The bearing support assembly has been machined in four separate parts (not shown in Fig. 3). This will enable them to be shimmed and realigned should any warpage occur during fabrication or operation.

Sufficient room has been left on the plate to allow the supports for the actuator, gear reducer and motor to be moved should a different type of load measuring system be employed.

4. SUMMARY

A direct shear apparatus has been designed and fabricated at CANMET for scale effects testing on jointed core received from AECL. The apparatus is capable of testing samples up to 30 cm by 20 cm at normal stresses up to 0.1 MPa. The loading mechanism can generate 50 kN of force over a displacement of 10 cm at displacement rates varying from 0.4 to 13 mm/min. The boxes themselves are equipped with mica heater strips and thermocouple arrays to allow for testing and recording at temperatures up to 200°C.

It should be noted here that this represents the preliminary design and fabrication of the direct shear apparatus. Experience dictates that considerable modifications will be necessary as the commissioning and calibration phases of the test program proceed. These will be detailed in subsequent reports. The intended methodology to be used in this study will also be outlined in a report to follow.

5. ACKNOWLEDGEMENTS

The authors would like to acknowledge Jose San Juan for his helpful suggestions during the fabrication of this equipment.

6. REFERENCES

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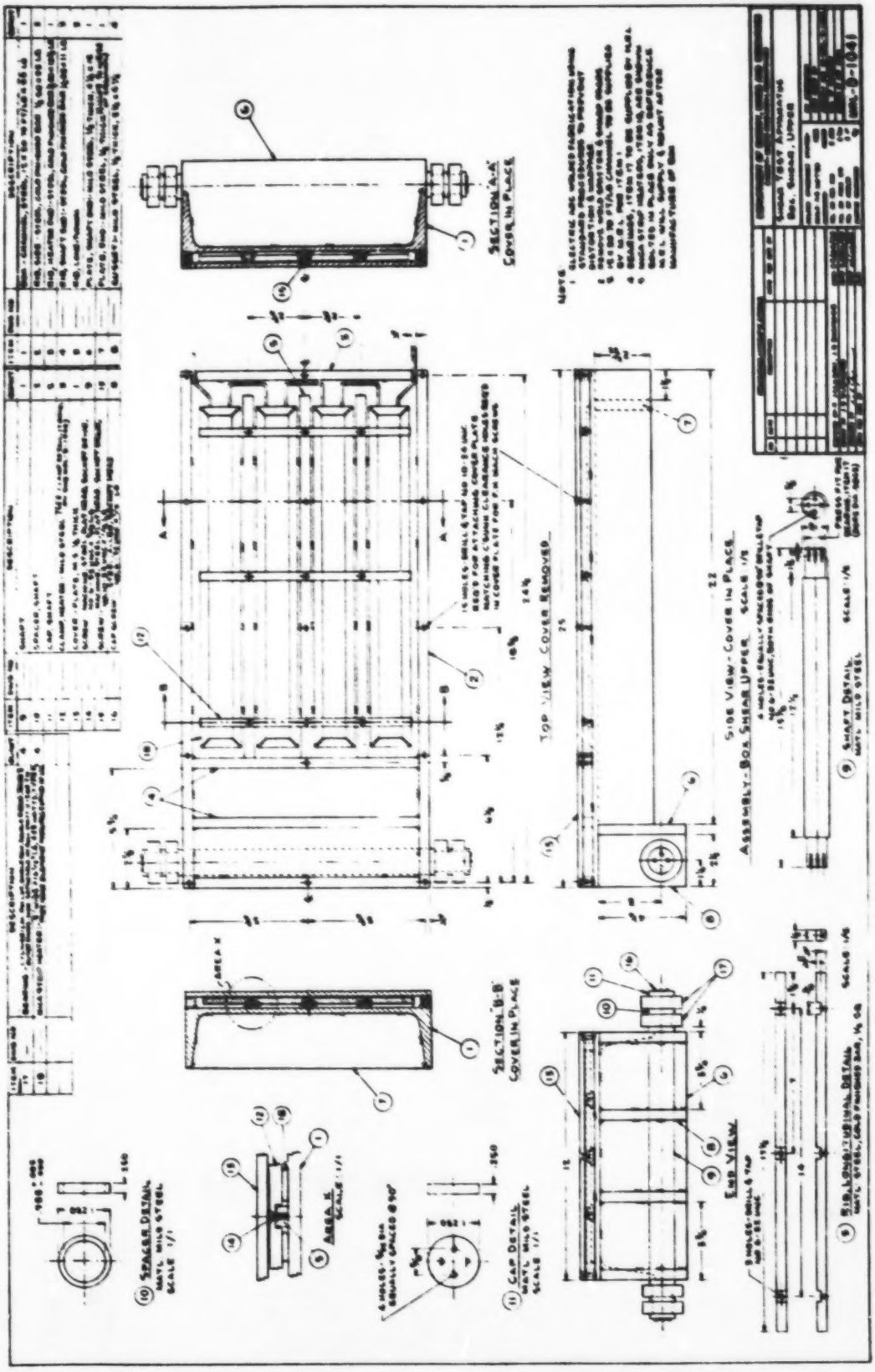

Fig. 1 - Upper shear box

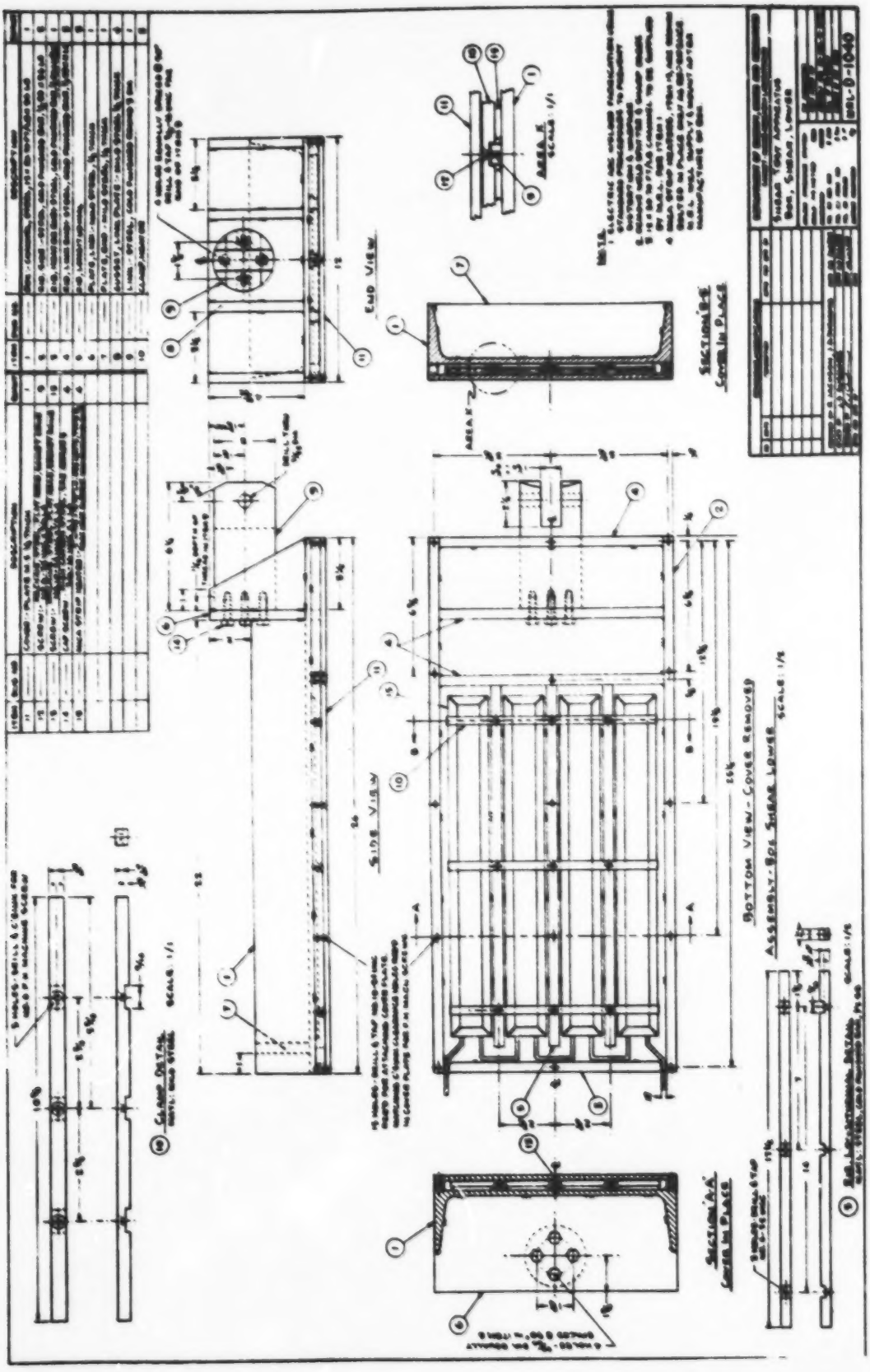

Fig. 2 - Lower shear box

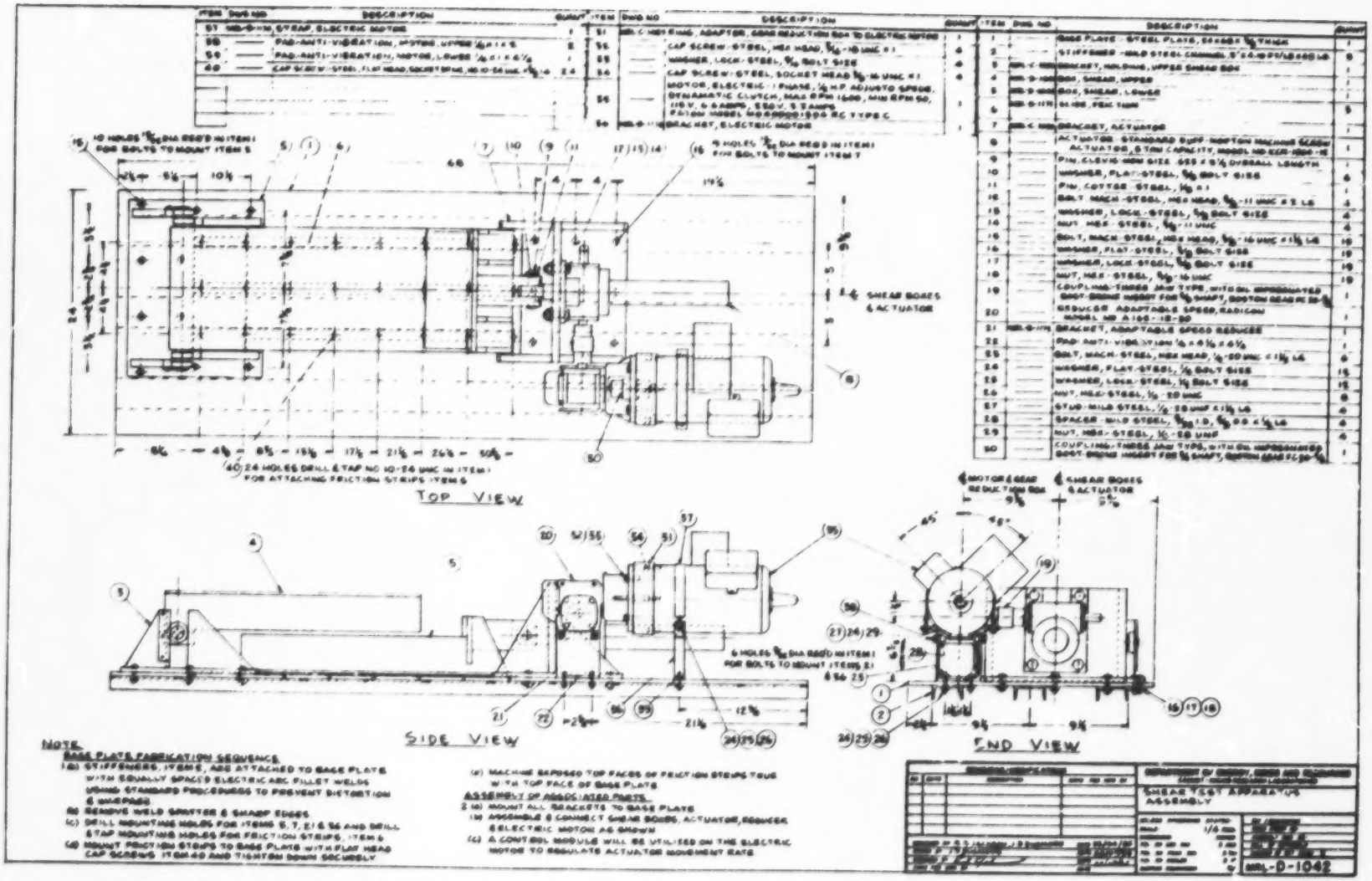

Fig. 3 - Shear test apparatus assembly